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Lead as a Membrane

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Chemical leads (defined by ASTM B29 as 99.85% minimum lead), sometimes called "soft lead," are used primarily in the chemical industry in environments that form thin, insoluble, and self-reparable protective films over the metal surface, e.g., solutions of salts such as sulfates, carbonates or phosphates. Against more soluble films such as nitrates, acetates or chlorides, lead offers little protection.

Alloys of antimony, tin, calcium, tellurium and arsenic offer some improvement in the mechanical properties of lead, but its usefulness is limited primarily by its poor structural qualities. "Hard lead" is lead alloyed with 1 to 13% antimony, usually about 6 to 8%. These alloys have greatly increased tensile strength, fatigue resistance, and hardness. Calcium in the range of 0.03 to 0.12% forms age-hardening alloys with lead. While these alloys age-harden at room temperature, that aging process might take 30 to 60 days. The tensile strength and stress-rupture resistance of the lead-calcium alloys may be improved by the addition of about 1.5% tin. However, this increases the aging time to 180 days. A 7% tin addition to lead is used to make bearings. Tellurium lead is chemical lead to which about 0.04% tellurium has been added. In wrought, and especially extruded lead products, the addition of tellurium retards grain growth and increases fatigue resistance. Arsenic, antimony, and tin act to harden lead and improve its physical characteristics up to about the boiling point of water. Some

grades of chemical lead have small percentages of silver and copper added to enhance the corrosion resistance and to improve its creep and fatigue resistance.

Lead, a heavy metal, has a low melting point and a high coefficient of expansion. It is a very ductile material that will creep under a tensile stress as low as 1 MP (145 lbf/in^2).

Because of its relatively poor room temperature creep resistance, lead is rarely used as a lining in tanks and other process equipment without some secondary support system.

It is possible to lead-line wood stave tanks but this is not a desirable application. Unlined wood tanks depend upon moisture in the process fluid to swell the wood and maintain the tight fit of the joints. When lined with lead, the wood staves dry and shrink. The hoops then have to be tightened to maintain structural integrity. This movement can cause damage to the lead lining.

An open steel basket-frame type construction can be used to overcome some of the problems noted with the use of lead lined wood vessels. Sheet lead straps are wrapped around the horizontal and vertical structural steel supports. The lead sheets are formed and weld attached to the noted straps. This type of construction is advantageous because it may be thoroughly inspected while in service. Faults are apparent and repairs easily made.

The most common practice is to line the steel vessel with lead as a corrosion resistant membrane barrier behind a ceramic brick or tile lining. The brick acts as a mechanical support for the lead as well as a thermal and wear resistant barrier to protect the weak soft lead from damage.

Tanks may be lead-lined by either the loose ("hung lead") or the bonded ("homogeneous") techniques.

After removing all weld beads, burrs, and other projections from the inside of the steel tank, the sheet lead is applied to the wall. It should be lapped over the top edge of the vessel and each sheet extended about 4 inches over those adjoining. The sheets should be welded together around the entire exposed edge. After the lead has been installed and tested, a layer of asbestos, ceramic or glass fabric or similar material, 1/16 to 1/8 inch thick, is added to act as a cushion between the brick and the lead to protect the lead against abrasion during expansion and contraction due to thermal changes.

A bonded lead lining is an effort to combine the corrosion resistance of lead with the superior structural strength of steel. Effectively, bonded lead is a layer of lead bonded to the steel to form a homogeneous or integral metallic structure. By effectively anchoring the lead to steel at all points of contact, relative movement between the two metals is minimized. The most common method of bonding includes a step by which the steel is "tinned." Following sand or grit blasting, chloride of zinc, zinc-ammonium chloride, stannous chloride or other flux materials are applied to the cleaned surface. This is followed by a torch application of a 50/50 lead/tin solder. To apply hard or soft lead by means of a torch, the heat is applied to the tinned steel only long enough to melt the tin coating, after which the torch heat is applied to the lead being applied. Usually, three coatings will build the lead thickness up to about ¼ inch. This same operation can be done without the pre-tinning step by using a 6% antimonial lead on the first coat application.

A more uniform thickness of lead may be achieved by holding a portable

dam a distance away from the prepared surface corresponding to the desired thickness of the lead lining. Molten lead is carefully poured onto the heated wall and dam. The dam is moved, and the operation repeated until the entire vessel is lead-lined. This technique is not unlike that of a concrete slip-form used in the construction of silos.

Sheet lead linings, at elevated temperatures, in addition to being subject to accelerated corrosion, tend to fail by some uncertain process, though not crystallization, causing embrittlement and/or inter-granular penetration, at temperatures above 165°F (73°C). If the vessel is to be exposed to such temperatures, a brick lining of a thickness to provide sufficient insulation to bring the shell temperature below this temperature is advisable. Figure 12-1 shows how such a brick lining may be installed. Note the layer of asbestos (now usually ceramic) paper between the lead and the brick, which paper functions to allow movement of the brick without seizing or abrading the lead.

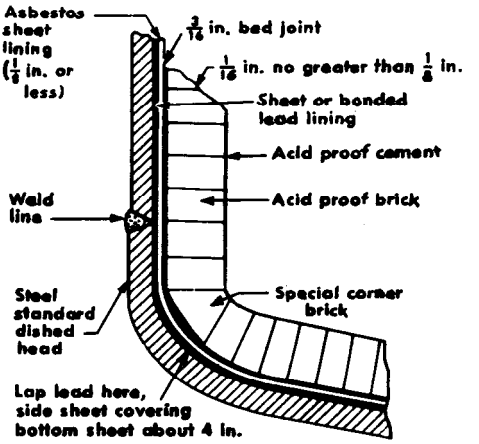
Asbestos sheet lining ($\frac{1}{8}$ in. or less)
$\frac{3}{16}$ in. bed joint
$\frac{1}{16}$ in. no greater than $\frac{1}{8}$ in.
Sheet or bonded lead lining
Acid proof cement
Acid proof brick
Weld line
Special corner brick
Steel standard dished head
Lap lead here, side sheet covering bottom sheet about 4 in.

Figure 12-1: When pressure is involved brick and lead lined tank bottoms are dished. Courtesy of Lead Industries Association.

Lead linings are most frequently found in the process equipment designed for sulfuric acid manufacture. As noted at the beginning of this chapter, this type of membrane is not indicated in exposures where the product of the reaction between the lead and the process chemicals is water soluble.

Figures 12-2 through 12-5 show the increases in the corrosion of lead membrane by various acids and mixtures of acids as temperatures rise. When lead is exposed to nitric acid, lead nitrate is formed. The resistance of the lead to further attack by the nitric acid depends on the solubility of this lead nitrate layer in the nitric acid, and this solubility in turn decreases with the increase of nitric acid concentration. This change in solubility is plotted in Figure 12-6.

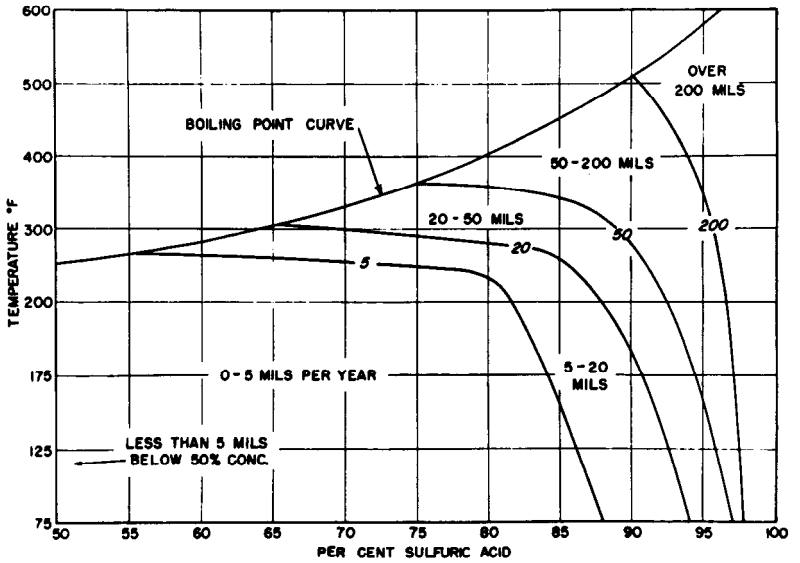

Figure 12-2: Corrosion of lead by sulfuric acid as a function of temperature. Courtesy of Lead Industries Association.

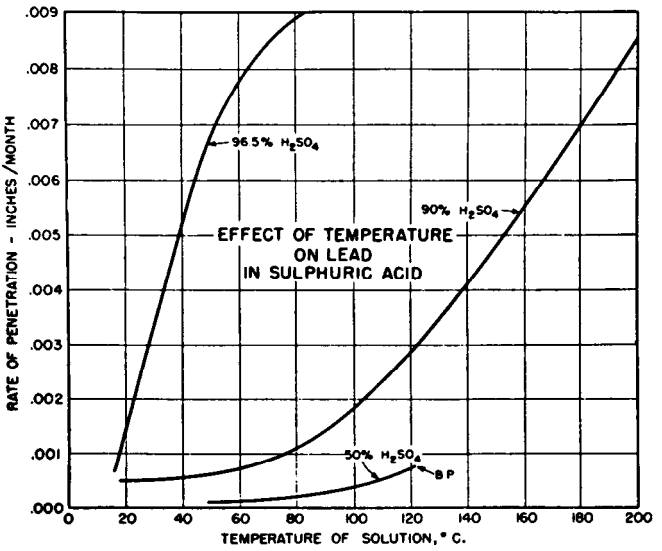

Figure 12-3: Effect of temperature on lead in sulfuric acid. Courtesy of Lead Industries Association.

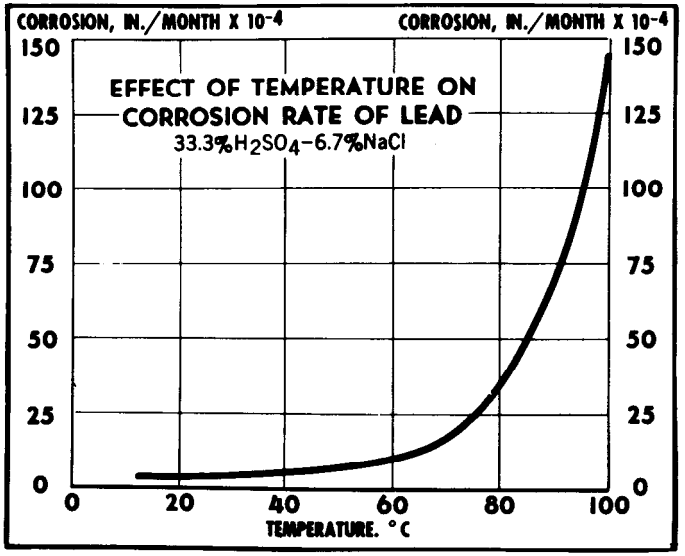

Figure 12-4: Courtesy of Lead Industries Association.

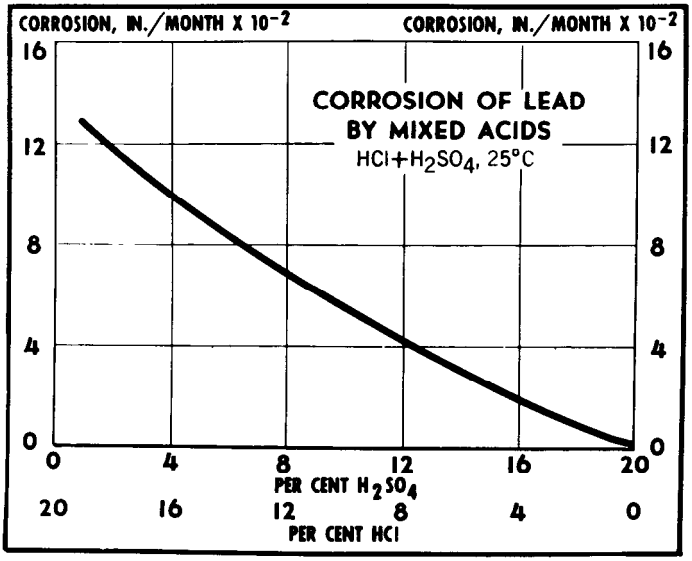

Figure 12-5: Corrosion of lead in mixed H_2SO_4 and HCl. Courtesy of Lead Industries Association.

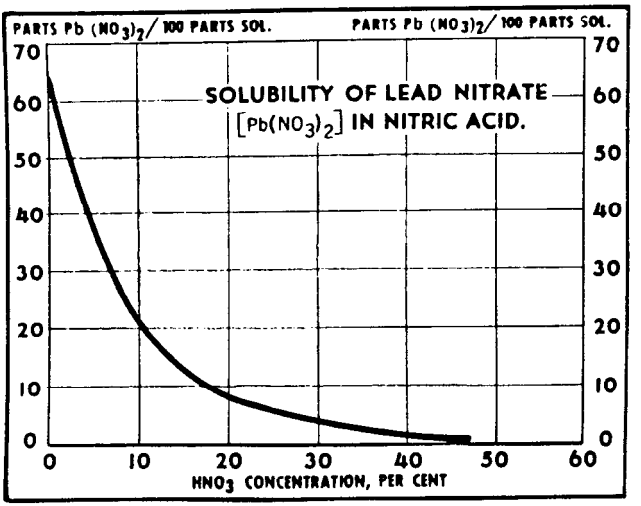

Figure 12-6: Solubility of lead nitrate in nitric acid. Courtesy of Lead Industries Association.

A brick lining has the secondary effect of protecting the lead from abrasion by contained slurries or suspended matter. The protective surface film of insoluble salts can be thinned or removed by such abrasion, and so the resistance to acids seriously affected. Figure 12-7 shows graphically how the velocity of a 20% sulfuric acid solution at 77°F, without any entrained solids, passing over the face of a lead lining can cause increasing corrosion as velocity increases.

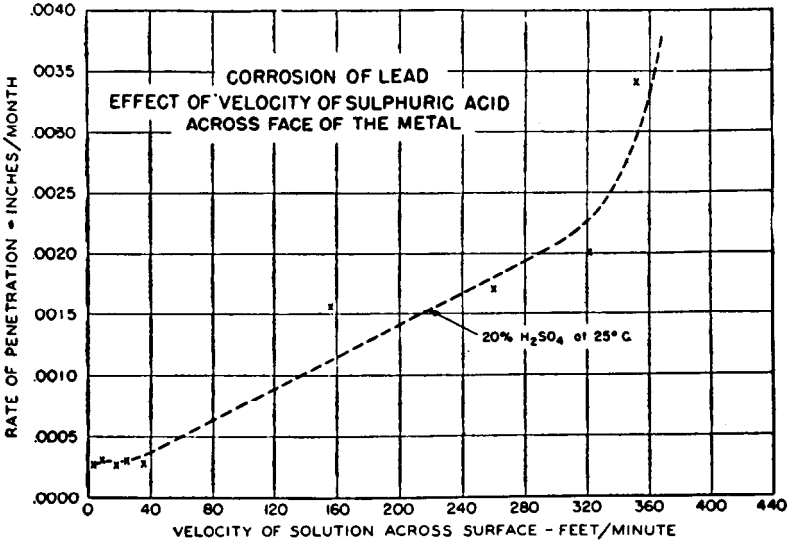

Figure 12-7: Effect of velocity on corrosion of lead in 20% sulfuric acid at 20°C. Courtesy of Lead Industries Association.

For detailed information about lead linings, their physical properties, and chemical resistance, the reader is referred to *Lead for Corrosion Resistant Applications: A Guide*, published by the Lead Industries Association, Inc., New York, NY.

Caution. Lead is an electrically conductive material. The designer should be careful not to place carbon brick and/or carbon-filled mortar in contact with or very close to lead linings where the service includes an electrolyte in solution, as lead and carbon will form a galvanic couple, with the carbon as anode and the lead cathodic. This will result in the wasting of the lead. If carbon brick or carbon-filled mortars are to be employed in the same design, an electrical insulating barrier should be placed between them and the lead. Such barriers may be Teflon® or other fluorocarbon sheet, a thick layer of a carbon-free, chemically inert mortar, or a thick layer of ceramic or organic fiber.